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Analysis of Production Equipment in a Production Organization

Miroslav Pristavka, Hristo Beloev, Pavol Findura,
Maciej Kubon, Grzegorz Dzieniszewski

Abstract: In the present paper we dealt with the issue of quality improvement in the production organization ZVS – Armory. According to the developed methodology, we investigated the capability of the production equipment. In the first measurement, all values were within the tolerance range, but they were not subject to normal distribution and were mainly in the upper tolerance range. Corrective measures had to be taken. The corrective measures were a change in production technology. On the next measurement, the measured values were in order, and it was possible to proceed to the calculation of the capability indices of the production equipment. The calculated values of the capability indices of the production equipment were $C_m = 5,900$ and $C_{mk} = 5,869$.

Keywords: quality improvement, measuring equipment capability, manufacturing equipment capability, manufacturing process capability

INTRODUCTION

In today's highly competitive era, organizations must withstand pressures and threats in both national and international markets. The successful operation of each of them, to a large extent, depends on the speed and ability to adapt to the demands of the market. Demands for product features from customers are becoming increasingly important. One of the most important characteristics of an organisation, therefore, is the ability to adapt to and meet the wishes and requirements of individual customers. (Bujna et al., 2019)

To maintain and improve quality, organisations need to know and use appropriate quality tools. By using effective tools, they can improve their market position, increase their competitiveness, productivity and, most importantly, reduce production costs. At the same time, the rapid development of technology makes it difficult for organisations to maintain quality at an appropriate level. The quality management process must therefore be carried out throughout the entire production process. Quality management is the way in which organisations will significantly increase customer satisfaction and also their market share. (Hučka, 2017)

MATERIALS AND METHODS

Nowadays, every organization needs to produce quality products, so the emphasis is on quality monitoring and quality improvement. By implementing various statistical methods, organisations can monitor and evaluate production processes and thus provide customers with proof that their requirements are being met. It is also important to improve the quality of production processes already in place and to introduce measures that can improve these processes. (Paulová, 2013)

The aim was to propose suitable quality management tools that will ensure quality improvement in the production process in the ZVS – Armory organization. The proposed methods were implemented in the production process of CNC machining of the selected part - extractor on the dimension $6,95^{+0}_{-0,050}$ mm.

The component being tracked is the extractor, which is part of the extractor system, a semi-automatic submachine gun. The dimension to be monitored is the width of the component (Fig. 1) $6,95^{+0,050}_{-0,050}$ mm, with a customer request for a tighter tolerance $6,95^{+0,030}_{-0,030}$ mm.

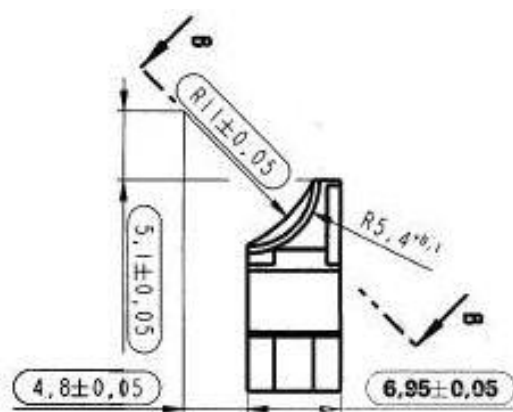


Fig. 1 Cutaway of the manufacturing drawing of the extractor component

Capability of production equipment Characteristics of the production facility

When detecting the fitness of a production machine, the CNC Feeler VMP 30A, it is necessary to select a control character. The control characteristic will be the width of the part of the extractor 6.95 ± 0.03 . It is also necessary to determine the boundary conditions viz:

- data of the production facility,
- process data,
- details of where the production facility is located.

The boundary conditions will be documented in the measurement record table.

Data acquisition

In the case of sampling, the production equipment shall be adjusted so that the measured values are in the centre of the tolerance field. Fifty samples shall be taken from the production process for testing. The samples shall be taken consecutively and shall be marked in order. The measured values shall be entered in the evaluation sheet, table, in the order in which they were taken from the plant. The individual values will then be plotted on a single value chart (Hrubec, 2016).

Evaluation of measured values

In the next evaluation procedure, it will be necessary to see if the measured values plotted on the individual value card are not arranged in a chaotic way or if these values show any trend. Should either of these possibilities occur, the process will have to be declared incompetent. Should the process be incapacitated, corrective action will need to be taken and the measurement will need to be repeated. Should neither of the possibilities be demonstrated and the measured values visually follow a normal distribution, the process may continue

Determination of the stability of measured values

From the measured values, artificial subgroups of the range $n = 5$. For each subgroup, the average value is calculated $\bar{X}_i$ and the standard deviation s_i (Hrubec, 2016).

Average character value $\bar{X}_i$ in a subgroup is calculated according to the equation:

$$\bar{X}_i = \frac{1}{n} \sum_{j=1}^k X_{ij} \quad (1)$$

for $i = 1, 2, \dots k$ and for $j = 1, 2, \dots n$,

where: i – serial number of a subgroup,

j – serial number of a measured value in a subgroup,

k – number of subgroups,

n – extent of subgroup,

X_{ij} – measured value in i -th subgroup.

Standard deviation in the subgroup:

$$s_i = \sqrt{\frac{1}{n-1} \sum_{j=1}^n (X_{ij} - \bar{X}_i)^2} \quad (2)$$

Calculated values $\bar{X}_i$ and s_i are plotted on the diagram on $\bar{X}$ – card and s – card obtain appropriate scales for both types of diagrams. The outliers must first be calculated $\bar{X}_{max}$, $\bar{X}_{min}$, s_{max}

The overall average value is then calculated $\bar{\bar{X}}$ according to the equation:

$$\bar{\bar{X}} = \frac{1}{k} \sum_{i=1}^k \bar{X}_i \quad (3)$$

and the average standard deviation $\bar{s}$:

$$\bar{s} = \frac{1}{k} \sum_{i=1}^k s_i \quad (4)$$

Determination of cut-off values for the mean and standard deviation

The mean position of the process under study can be considered stable if the individual values of $\bar{X}$ do not exceed the upper limit of the intervention $HMZ_{\bar{X}}$, to be calculated:

$$HMZ_{\bar{X}} = \bar{\bar{X}} + 1,3 \cdot \bar{s} \geq \bar{X}_{max} \quad (5)$$

or lower limit of intervention $DMZ_{\bar{X}}$ to be calculated:

$$DMZ_{\bar{X}} = \bar{\bar{X}} - 1,3 \cdot \bar{s} \leq \bar{X}_{min} \quad (6)$$

If the largest observed standard deviation of the groups of five s_{max} less than 2,1. s , then the standard deviation can be considered stable.

$$HMZ_s = 2,1 \cdot \bar{s} \geq s_{max} \quad (7)$$

Stability tests are performed to ensure that there are no disturbing elements affecting the process. If the means and standard deviations lie within the limiting poly, statistical evaluation can begin. If the values are outside the field, the cause must be found, eliminated and the measurement repeated

Calculation of the capability indices of production equipment C_m a C_{mk}

To determine the capability index of a production facility C_m and the corrected index of capability C_{mk} the average of all measured values must be calculated $\bar{X}_N$ and determine the standard deviation of all measured values σ_{N-1} . The average value $\bar{X}_N$ shall be calculated:

$$\bar{X}_N = \frac{1}{N} \sum_{i=1}^N X_i \quad (8)$$

Where: $i = 1, 2, \dots, N$,

X_i - i -th value of the measured character

Standard deviation σ_{N-1} is calculated:

$$\sigma_{N-1} = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (X_i - \bar{X}_N)^2} \quad (9)$$

Where: N – the total number of measured values

Capability index of the production facility C_m is then calculated:

$$C_m = \frac{USL - LSL}{6 \cdot \sigma_{N-1}} = \frac{T}{6 \cdot \sigma_{N-1}} \quad (10)$$

Where: T – tolerance,

USL , LSL – upper and lower tolerance values

The minimum requirement for the capability index of a production facility shall be $C_m \geq 1,66$.

Corrected index of production equipment C_{mk} which takes into account the position of the mean value $\bar{X}_N$ is calculated according to the equations:

$$C_{mk} = \frac{USL - \bar{X}_N}{3 \cdot \sigma_{N-1}} \quad (11)$$

$$C_{mk} = \frac{\bar{X}_N - LSL}{3 \cdot \sigma_{N-1}} \quad (12)$$

The smaller value of the two formulas is used for evaluation. The minimum requirement for the corrected capability index of a production facility shall be $C_{mk} > 1,61$

RESULTS

Monitoring, measurement and analysis

The organization has planned and implemented measurement, data collection and validation through a quality management system to ensure performance, to ensure the conformity of the manufactured parts to the customer's specific requirements. To ensure continuous improvement of the effectiveness of the quality management system, the organisation obtains information from customers and consumers of the final products.

Capability of production equipment Characteristics of the production facility

The manufacturing process of the investigated component was carried out on a CNC machine called Feeler VMP 30A (Fig. 2), which is shown in the figure. It is a vertical machining centre of the VMP series. The dimensions of the worktable are 890 x 420 mm; the maximum load of the work table is 300 kg. The maximum spindle speed is 10 000 min⁻¹. The width of the machine is 2100mm; the maximum height is 2370mm; the weight is 3300kg.

There are currently 4 such CNC machines in the company and they are used for the production of both simpler and more complex parts.

The production equipment is a Feeler VMP 30 A CNC milling machine, and the selected control feature was the width of the part to be monitored, the extractor. The boundary conditions were determined, which are given by in the table. (Jančichová, 2020)



Fig. 1 Vertical CNC machine Feeler VMP 30A

Data acquisition

The production process was sampled every 3 hours during the production process. The samples were numbered in the order in which they were taken. The measured values were entered in a table, which was also used to create a tab of the individual values

Table 1 Form for evaluation of the suitability of a production equipment

ZVS – Armory	Form for evaluation of the suitability of a production equipment									
Part: Extractor					Controlled dimension: 6.95 ^{+0.03} _{-0.03} mm					
Machine: Feeler VMP 30 A		Marginal conditions								
		Performance: 7.5 kW		Voltage: 380 V		Noise: 68 – 70 dB		Tools: Automatic tools		
Temperature: 24.5 °C		Speed: 10 000 min ⁻¹		Shift: 3.6 mm.min ⁻¹		Cooling emulsion: Hydrol ZUBORA				
Humidity: 50%										
Measured values										
No.	mm	No.	mm	No.	mm	No.	mm	No.	mm	
1	6.954	11	6.958	21	6.973	31	6.978	41	6.967	
2	6.956	12	6.959	22	6.965	32	6.965	42	6.974	
3	6.957	13	6.964	23	6.963	33	6.967	43	6.974	
4	6.957	14	6.965	24	6.967	34	6.974	44	6.974	
5	6.956	15	6.966	25	6.962	35	6.968	45	6.974	
6	6.958	16	6.969	26	6.961	36	6.975	46	6.973	
7	6.958	17	6.962	27	6.962	37	6.978	47	6.969	
8	6.961	18	6.966	28	6.966	38	6.982	48	6.97	
9	6.959	19	6.979	29	6.966	39	6.976	49	6.972	
10	6.96	20	6.975	30	6.965	40	6.969	50	6.967	
Values measured card										

Evaluation of measured values Investigating the regularity of measured values

From the table of individual values (Tab. 1), it was assessed that the measured values are chaotically arranged, located in the upper part of the tolerance field and do not follow a normal distribution. Therefore, after consultation, corrective action was taken and the measurements were repeated. The corrective measures were a change in the production technology of the component.

Data recovery

After corrective action, a change in technology, 50 manufactured parts were taken out of the process again, at a time interval of 3 hours and the measurement was repeated. The measured values are shown in tab. 2.

Evaluation of measured values

It could be evaluated from the form of the individual measured values that the measured values are not subject to any trends, are not chaotically arranged and are subject to a normal distribution. It was possible to move on the determination of stability.

Determination of stability of measured values

From the measured values, subgroups of $n = 5$ were formed, and for each subgroup, the mean $\bar{X}_i$ and standard deviation S_i were calculated according to Eq. The results are presented in the table.

Table 2 Form for evaluation of the suitability of a production equipment

ZVS – Armory		Form for evaluation of the suitability of a production equipment																								
Part: Extractor					Controlled dimension: 6.95 ^{+0.03} _{-0.03} mm																					
Machine: Feeler VMP 30 A		Marginal conditions																								
		Power: 7.5 kW		Voltage: 380 V		Noise: 68 – 70 dB		Tools: Automatic tool																		
Temperature: 24.5 °C		Speed: 10 000 min ⁻¹		Shift: 3.6mm.min ⁻¹		Cooling emulsion: Hydrol ZUBORA																				
Humidity: 50%																										
Measured values																										
No..	mm	No.	mm	No.	mm	No.	mm	No.	mm																	
1	6.952	11	6.947	21	6.952	31	6.952	41	6.953																	
2	6.949	12	6.949	22	6.951	32	6.952	42	6.951																	
3	6.951	13	6.950	23	6.947	33	6.947	43	6.949																	
4	6.95	14	6.952	24	6.953	34	6.949	44	6.948																	
5	6.948	15	6.951	25	6.950	35	6.953	45	6.951																	
6	6.95	16	6.951	26	6.948	36	6.952	46	6.950																	
7	6.949	17	6.949	27	6.953	37	6.948	47	6.948																	
8	6.95	18	6.948	28	6.949	38	6.949	48	6.95																	
9	6.949	19	6.951	29	6.95	39	6.952	49	6.952																	
10	6.951	20	6.95	30	6.951	40	6.952	50	6.949																	
Values measured card																										
6,954 6,953 6,952 6,951 6,95 6,949 6,948 6,947 6,946 6,945 6,944 <table><tr><td>1</td><td>4</td><td>7</td><td>10</td><td>13</td><td>16</td><td>19</td><td>22</td><td>25</td><td>28</td><td>31</td><td>34</td><td>37</td><td>40</td><td>43</td><td>46</td><td>49</td></tr></table>										1	4	7	10	13	16	19	22	25	28	31	34	37	40	43	46	49
1	4	7	10	13	16	19	22	25	28	31	34	37	40	43	46	49										

Table 3 Measured values

No.	Measured values, mm					$\bar{X}_i$	s_i
	X_1	X_2	X_3	X_4	X_5	mm	mm
1	6.952	6.949	6.951	6.95	6.948	6.95	0.00045
2	6.95	6.949	6.95	6.949	6.951	6.9498	0.00024
3	6.947	6.949	6.950	6.952	6.951	6.9498	0.00055
4	6.951	6.949	6.948	6.951	6.95	6.9498	0.00037
5	6.952	6.951	6.947	6.953	6.950	6.9506	0.00066
6	6.948	6.953	6.949	6.950	6.951	6.9502	0.00055
7	6.952	6.952	6.947	6.949	6.953	6.9506	0.00072
8	6.952	6.948	6.949	6.952	6.952	6.9506	0.00056
9	6.953	6.951	6.949	6.948	6.951	6.9504	0.00056
10	6.95	6.948	6.95	6.952	6.949	6.9498	0.00042

The overall average value was then calculated $\bar{\bar{X}}$:

$$\bar{\bar{X}} = \frac{1}{k} \sum_{i=1}^k \bar{X}_i = \frac{1}{10} \sum_{i=1}^k 6,95 + \dots + 6,949 = 6,9501 \text{ mm}$$

and the average standard deviation $\bar{s}$:

$$\bar{s} = \frac{1}{k} \sum_{i=1}^k s_i = \frac{1}{10} \sum_{i=1}^k 0,00045 + \dots + 0,00042 = 0,00051$$

Determination of limit values for the average value $\bar{X}_i$ and standard deviation s_i

The values for the mean $\bar{X}_i$ were calculated – the upper limit:

$$HMZ_{\bar{X}} = \bar{\bar{X}} + 1,3 \cdot \bar{s} \geq \bar{X}_{max} \rightarrow 6,9508 > 6,9506 \text{ mm}$$

and the lower limit:

$$DMZ_{\bar{X}} = \bar{\bar{X}} - 1,3 \cdot \bar{s} \leq \bar{X}_{min} \rightarrow 6,9495 < 6,9498 \text{ mm.}$$

The calculated values of $\bar{X}_i$ and the limiting values of $HMZ_{\bar{X}}$ and $DMZ_{\bar{X}}$ for the average value of $\bar{X}_i$ are plotted on the X – diagram in the figure.

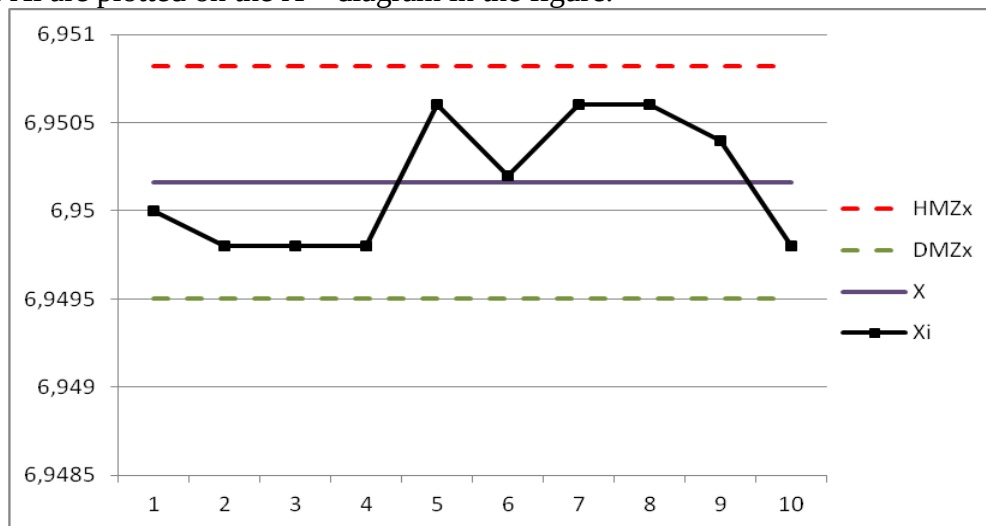


Fig. 3 X- card

Subsequently, the upper limit of the HMZ_s hit for the standard deviation s_i was calculated:

$$HMZ_s = 2,1 \cdot \bar{s} \geq s_{max} \rightarrow 0,00107 \geq 0,00072 \text{ mm.}$$

The calculated values of the standard deviation s_i and the upper limit of the HMZ_s :

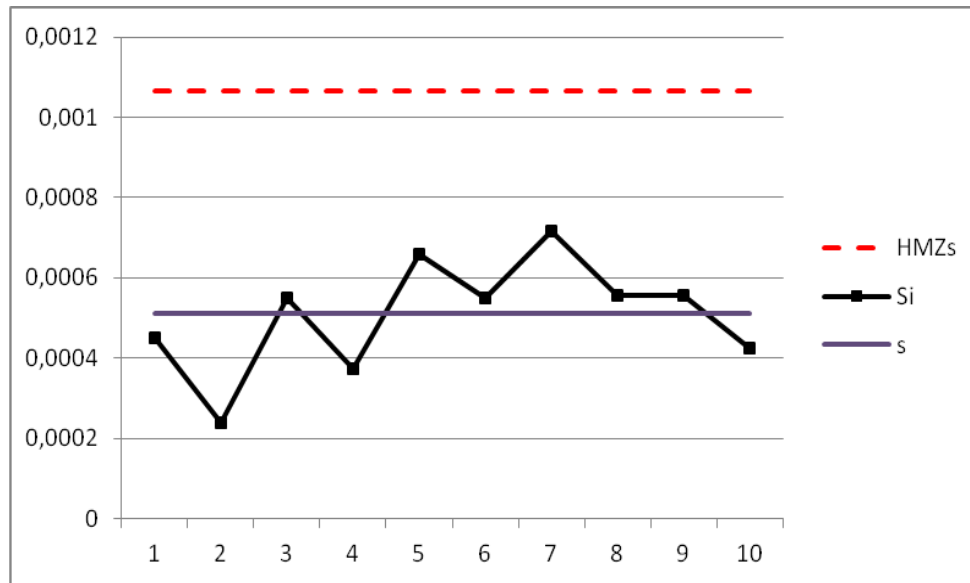


Fig. 4 s- card

The stability tests showed that there were no disturbing elements acting on the process and it was possible to proceed with the calculation of the capability indices of the production facility C_m and C_{mk} .

Calculation of the capability indices of the production facility C_m and C_{mk}

To calculate the capability indices of the production facility C_m and C_{mk} , the average of all measured values X_N had to be calculated:

$$\bar{X}_N = \frac{1}{N} \sum_{i=1}^N X_i = \frac{1}{50} \sum_{i=1}^N 6,952 + \dots + 6,949 = 6,9501 \text{ mm}$$

and the standard deviation of all measured values σ_{N-1} :

$$\begin{aligned} \sigma_{N-1} &= \sqrt{\frac{1}{N-1} \sum_{i=1}^N (X_i - \bar{X}_N)^2} = \\ &= \sqrt{\frac{1}{50-1} \sum_{i=1}^N (6,952 - 6,9501)^2 + \dots + (6,949 - 6,9501)^2} \\ &= 0,00169 \text{ mm.} \end{aligned}$$

It was then possible to proceed to the calculation of the capability index of the production equipment C_m :

$$C_m = \frac{USL - LSL}{6 \cdot \sigma_{N-1}} = \frac{T}{6 \cdot \sigma_{N-1}} = \frac{0,060}{6 \cdot 0,00169} = 5,9009$$

and corrected index C_{mk} :

$$C_{mk} = \frac{USL - \bar{X}_N}{3 \cdot \sigma_{N-1}} = \frac{6,980 - 6,9501}{3 \cdot 0,00169} = 5,8694$$

$$C_{mk} = \frac{\bar{X}_N - LSL}{3 \cdot \sigma_{N-1}} = \frac{6,9501 - 6,920}{3 \cdot 0,00169} = 5,9324$$

CONCLUSION

The capability of the production equipment of the Feeler VMP 30 A CNC machine was evaluated. Fifty samples were taken, labelled in the order in which they were taken. In the first measurement, the measured values were within the tolerance range, but after plotting the values on the chart, it was found that the values did not follow a normal distribution. Corrective action had to be taken and this was to change the manufacturing technology of the extractor component. On re-measurement, the measured values were again recorded on the form and recorded on the individual value card. The values were subject to a normal distribution and so could be divided into artificial subgroups, the mean $\bar{X}_i$ values calculated and the standard deviation s_i for each subgroup. The joint mean value of $\bar{X}$ and the mean standard deviation of s were then calculated. Before applying the mean values to the $\bar{X}$ - card, the upper limit of the HMZ $\bar{x}$ hit and the lower limit of the DMZ $\bar{x}$ hit were calculated. Also, the upper hit limit for the standard deviation of the HMZs was calculated and the values of the standard deviation of s_i were plotted on the s - card.

From the previous results, it was possible to move on to the calculation of the manufacturing equipment capability indices C_m and C_{mk} . The requirements for the manufacturing equipment capability indices were met with $C_m = 5.900 > 1.66$ and $C_{mk} = 5.869 > 1.67$, respectively.

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Quality of Repair Services

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Abstract: *The article clarifies what content is included in the concept of quality of repaired machines and repair services and what is the essence of this concept. The main reasons for ensuring a high level of quality are relevant and important for modern repair production and repair services offered. The importance of the connection between business, management, machine repair processes, quality and reliability of repaired machines and offered repair services is presented. The principles that reflect the diversity in the understanding of the concept of quality of the repair service, as well as its perception are indicated.*

Keywords: *quality, repair, service.*

INTRODUCTION

In today's conditions of growing competition on a global scale, quality issues are among the most actual and important issues of any company and activity. Improving the quality of products and services is one of the main directions in the development of technical progress and successful implementation of products and services [1, 2]. Achieving high quality products and services is not only an economic and technical issue, but it also has a social aspect.

Quality is an important factor in raising living standards, economic, social and environmental safety. It is a complex concept that characterizes the efficiency of all aspects of repair production. The problem of ensuring a high level of quality of products and services is and remains relevant. It is a strategic problem, the solution of which depends on the economic stability of each country [3, 4, 5].

The purpose of the article is to clarify the concept of quality of repair services.

STUDY OUTLINE

The repaired machine is a product of the repair production and must have a certain level of quality. The repair of machines is a type of service, because its implementation does not create a new product. In other words, there is no new machine, but only the repaired machine with a fully restored resource. In this sense, services are defined as intangibly dominated products, the result of the application of certain efforts to people and objects. At the beginning of the twenty-first century, services occupied an increasing place worldwide, where 80% of the workforce was employed in this field. Bulgaria is not an exception; services also increase their share in the gross domestic product and become a major source of income for the population [5, 6, 7, 9, 10].

The growth of the market of repair services and the competition require an effort in the direction of improving their quality. The oversaturated market creates more and more demanding and demanding customers. They are looking for reliable repaired machines and services that will meet not only their requirements, but also ideas. The high quality of the offered repair services makes the company more competitive, resistant to crises and increases its market share.

The main reasons why ensuring a high level of quality is relevant and important for modern repair production and repair services are:

Quality is a key element for the purchase of the repaired machine or service from the consumer's point of view. You are more likely to lose orders due to a low level of quality than from excessively high prices;

The quality is comprehensive. Companies carry out many different activities to compete. Quality management systems offer a set of actions covering all phases of the production process (marketing, planning, personnel, innovation, technology, etc.) to stay on the market;

Quality is the main tool for reducing costs. It is always cheaper to repair the machine

the first time than to fix it afterwards;

Quality strengthens the company's position in the market. In a market economy, the level of quality of repair products and services is decisive in competition;

Quality is important not only for repair production, but also in marketing, development, service, etc.

It should be noted that the concept of service quality is multifaceted. It includes the quality of the organization, economic calculations, the technological process of machine repair, environmental parameters, socio-psychological relations, ethical norms, legal, political relations and more. Each component contributes to the level of quality of the services provided [1 - 4]. According to experts, the quality of the repair service depends on the capabilities of the company itself and is associated primarily with the idea of it.

There is diversity in the understanding of the concept of quality of the repair service, as well as its perception. It is based on several different principles that reflect its diversity:

The quality of the repair service can be measured objectively. The objective quality of the service means measurable values. Differences in quality can be quantified according to repaired machines and repair services;

The quality of the repair service must be user-oriented. According to them, the quality of repair products is in the first place in its subjective evaluation. The subjective quality of the repair service is a result of the customer's perception; therefore the repair service that satisfied one customer may be of poor quality for another customer. Consumers have a variety of requirements, repair products and services that meet these needs are determined by the highest quality;

Repair services cannot be stored, this is a result of their immateriality. They are actions aimed at making the inoperable machine operational, they cannot be touched, tasted or smelled, nor can they be possessed;

In terms of cost-effectiveness ratio, the quality of repair services is manifested through cost and price. Quality repair products and services perform a certain function at an affordable price, and also meet the standards at reasonable costs.

The quality of the repaired machine and offered repair service are interrelated, but at the same time they have a big difference. While the quality of the repaired machine depends on its characteristics, the service can be interpreted as a process from the first contact with the customer to the feedback on the use of the repaired machine by this customer. That is why if we want to determine whether a company provides quality repair services, we must follow the whole process.



Fig. 1 Connection between business, management, processes, quality and reliability of the repaired machines and services

The quality of the repaired machines and offered services is directly dependent on the material and technical base of the repair production, the level of technology, the organization, the material and technical supply and the realization. It depends to a large extent on the qualification of the managerial and executive staff. Such a view orients us to the understanding that the quality of the repaired machines and repair services is a function of the quality of the processes on the basis of which the repair service is created as shown at Fig.1.

They, in turn, are the result of the quality of the system within which the machines are repaired. The environment in which the system operates plays a huge role in the quality of the system as a whole. Improving the quality of repaired machines and services is a complex and multifaceted process of great importance which reflects the efficiency and competitiveness of repair products on the market.

The business and management are strongly connected to the quality and reliability of the repaired machines and services within conditions of developed economic market. Modern practice shows that there can be no successful business without high quality and reliable goods and services. Business is the activity of making a profit from the production or trade of goods and services. The profit of the business depends on the marketability of the products from repaired machines and repair services. The ability of the product to be sold on the market is determined by its quality. The first thing that needs to be clarified when talking about the quality of repair services is what it is and what content is included in this concept. In order to be able to talk about the quality of the repair service, the service potential of the company, the service process and the results of the provided repair service are important. The service potential of the company includes the capabilities of the person (managers and workers) and the infrastructure of the company. The service process refers to the performance of the repair service provided, ie how quickly the service is provided. The results of the provided repair service are the perception of the customers. Since the purpose of the provided repair service is to create customer satisfaction, the quality of the service should be measured in a customer-oriented way [5, 6, 8].

Quality as a philosophical category expresses the inseparability of the existence of the object from its essential definition. It is related to the object as a whole, expressing its essence and is inseparable from it. Quality is relative, it is determined for a given period of time, changing for different periods.

The concept of quality has been studied since Aristotle in the third century BC. He defines it as differences between objects or a division of the principle of "good and bad". Hegel defines quality as identical with the definiteness of being, therefore, something ceases to be there when it exists, if it has lost its quality. Schuhart believes that quality is composed of objective physical characteristics and the subjective side (the perception of these things). According to Ishikawa, quality is a property that really satisfies consumers. In Chinese, the character for quality consists of two elements, "equilibrium" and "money."

According to the ISO 9000 standard, "Quality is the set of properties and characteristics of a product related to its ability to meet agreed or anticipated needs".

For the Japanese JIS standard, "Quality represents all the characteristics and performance of a product or service that can be evaluated to determine whether the product or service meets the purposes of its use."

In BDS "Quality is a set of properties of the product, determining its suitability to meet certain needs in accordance with its purpose."

All understandings and standards define quality as a set of properties that meet the needs and / or requirements of users. The satisfied consumer repeatedly returns to buy again and again the desired quality repair product or service, in other words, "Quality is the product that is not returned to you, but the consumer returns to buy it again."

What has been said so far about the quality of repair services can be summarized through the key quality criteria, namely customer satisfaction, consumer satisfaction. Consumer needs are diverse and complex. Depending on the cultural level, they express different needs that can be identified or anticipated. Satisfied customer requirements increase sales, improve reputation and expand the market share of the repair company [5 - 10].

The quality of the repaired machines or services is a result of the activity of a separate repair company, but the specific assessment of the quality is given by the external environment by the user of the repaired machine or the repair service. This makes quality a subjective concept. In this sense, whatever the vision of a repair company, it is important the customer's assessment of the quality of the repair service. This is the most important point in the philosophy of quality and should be taken into account by anyone involved in providing repair services.

CONCLUSIONS

1. It is clarified what content is included in the concept of quality of repaired machines and repair services and what is this concept.
2. The main reasons for ensuring a high level of quality are relevant and important for modern repair production and repair services offered.
3. The importance of the connection between business, management, machine repair processes, quality and reliability of repaired machines and offered repair services is presented.
4. The principles that reflect the diversity in the understanding of the concept of quality of the repair service, as well as its perception are indicated.

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Implementation of Statistical Control to Production Process

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Abstract: Statistical process control (SPC) is a preventive approach to quality management. It aims to maintain the process at a stable level over the long term by collecting available data. SPC offers a number of tools to achieve this goal. The aim of this paper was to describe the essence of some selected tools and to analyse the possibility of their implementation in the environment of ZF Slovakia organization. We used a cause and effect diagram to solve the problem of an incapacitated measurement system. A histogram was constructed based on the measurement results of the damper component. Using the analysed SPC methods and related data, certain areas that offer room for improvement will be defined.

Keywords: statistical methods, quality, quality management

INTRODUCTION

Today, quality is considered one of the most effective tools for competitiveness. Manufacturing organisations take several features into account when selecting new supply partners. In addition to the price of the offered semi-finished product or component, geographical location, quality appears at the top of the indicators of the supplier's ability to deliver the desired product. (Hrubec, Cservenáková 2018)

In many cases, quality is seen as synonymous with increasing costs. Most of the time, this is because a quality product is considered to be one that has been subjected to many additional checks. This is, of course, a mistaken view, because quality should not be additionally checked, but produced. If we would like to develop this attitude further, the emphasis should be on prevention - on anticipating those factors that prevent us from producing a quality product. And that right first time. So, as far as the attitude to industrial quality is concerned, instead of asking "Did we get it right?" it is more relevant to ask the question "Can we make it right?" or "What do we need to get it right?". (Korenko et al., 2019)

However, estimating some impacts could be difficult and even impossible without mathematical calculation. And it is precisely in this ability of the organisation that lies an enormous opportunity to increase the quality of production and thus competitiveness in the market. (Markulík et al., 2019)

Statistical process control offers a range of tools that allow you to estimate how a process will behave over a broader period of time by analysing a specific time period of a process. Based on this knowledge, the process can then be corrected.

MATERIALS AND METHODS

Statistical quality management represents a huge potential for increasing the efficiency of an organisation through quality improvement. Understanding some of the methods requires a certain level of knowledge, which those responsible acquire through additional self-study or by attending external or in-house training. The introduction of SPC thus not only improves the quality management system but also develops the working capital entering the system.

The aim was to describe the essence of selected statistical methods and to demonstrate the possibility of their implementation in the production process. The possibility of their use in the industrial environment of the ZF Slovakia organization was presented by means of concrete examples.

An important point in the implementation of SPC is the collection of data. The data formed the basis of the description for the practical implementation of SPC methods.

As for the software used, for us it was MS Excel, which we used as a spreadsheet editor, and Minitab 18 for statistical calculations.

A cause and effect diagram is a useful tool for clearly plotting and analysing the root

cause. It has a strong potential application in the analysis of customer complaints or scrap impact factors as well as various other production and non-production problems.

Steps in creating a diagram:

- the problem to be addressed is identified. This problem represents the head of the fish skeleton,
- the problem solving team names all the causes of the problem that come into consideration. These problems form the branches (bones) of the diagram and may also have sub-causes (branches). (Terek, Hrčiarova, 2004)

The basis of the procedure is to sort the whole data set into so-called **classes**, i.e. partial intervals of selected length. An interval is defined for the whole set, the boundaries of which are defined by suitably rounded numbers. The boundaries of the classes are also chosen as suitably rounded numbers. All the values obtained by measuring the quantity to be monitored shall be divided into groups belonging to the appropriate classes. The number of numbers in a given class indicates the frequency with which the observed variable takes on values within a defined interval. (Hrubec et al., 2009)

If the observed quality characteristic has a normal distribution, then the histogram should have a bell-shaped pattern, which indicates that only random influences are acting on the process and that it is in a statistically manageable state. Any deviation of the histogram from this shape then signals the likely action of definable influences. If tolerance limits are plotted in the histograms, an estimate of the process capability can be made and, in the case signalling an incapable process, possible solutions to increase capability can be considered. (Škultéty, 2021)

The normal (normal, Gaussian, bell-shaped) distribution of a variable is characterized by the fact that 68.26% of the population is contained within an interval of no more than one standard deviation from the mean. 95.45% are within an interval of at most two standard deviations and 99.73% are within an interval of at most three standard deviations. (Oakland, 2008)

RESULTS

Cause and effect diagram

In the ZF measurement lab we solved a problem with the measurement system - measuring the plastic pad with a contour gauge (Fig. 2). The evaluated characteristic was the curve profile according to Fig. 1. As expected, the measuring station should be able to measure this characteristic, however, when calculating the capability of the measurement system, we got a value of the total scatter band (SM %) above 40%, which indicates that the measurement system is not capable.

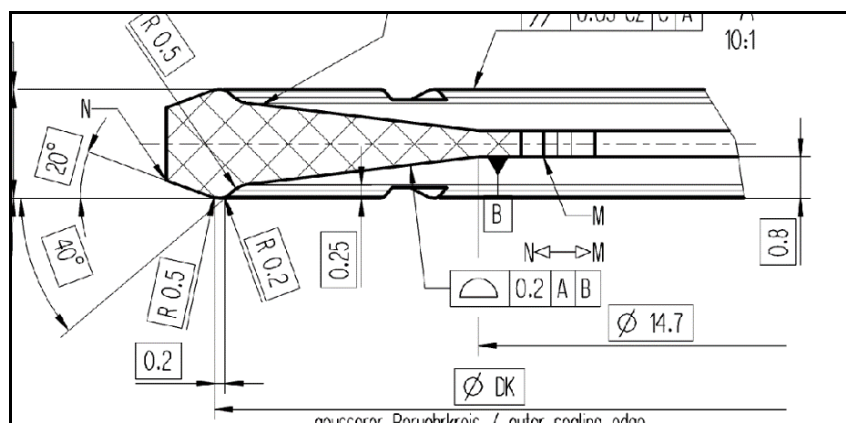


Fig. 1 Specification of the profile

We analysed the problem by means of a short spontaneous brainstorming session, to which the laboratory staff and the metrologist were invited. The factors that could have influenced the problem were written down in a cause and effect diagram (Fig. 3). Since it would be laborious and time-consuming to test each factor separately, we decided to vote for the most likely causes affecting the outcome. (Škultéty, 2021)

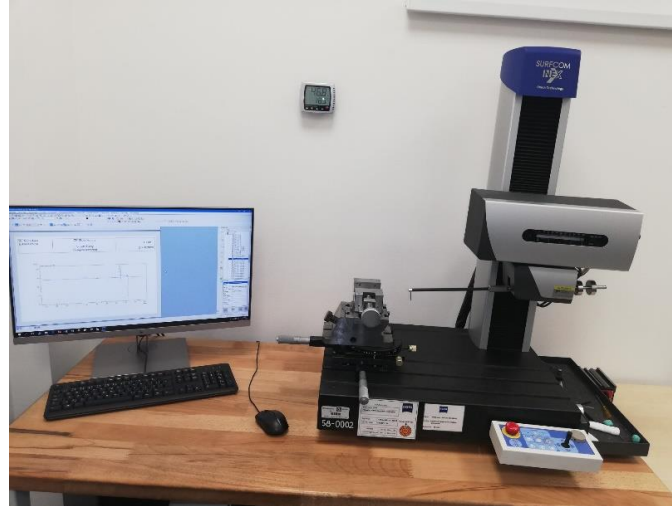


Fig. 2 Measuring station

Each worker was given the opportunity to vote for the four causes they thought most likely. It was decided that we would address the three factors that received the most votes first. The collective ranked the following as the most likely causes: an uncalibrated sensor, too much variability in the dimension of one part, and improper fixing of the part. When verifying these factors, it was found that the observed dimension does indeed have some variability in a single part, so it was necessary to mark the exact measurement path on each part. The sensor was calibrated, and the machine itself was found to be accurate. After repeating the fit analysis, the results were still not satisfactory. Therefore, we decided to fine-tune the measurement program at the level of feature sensing in the software. After the third attempt, the R&R result was satisfactory and the measurement system was declared fit.

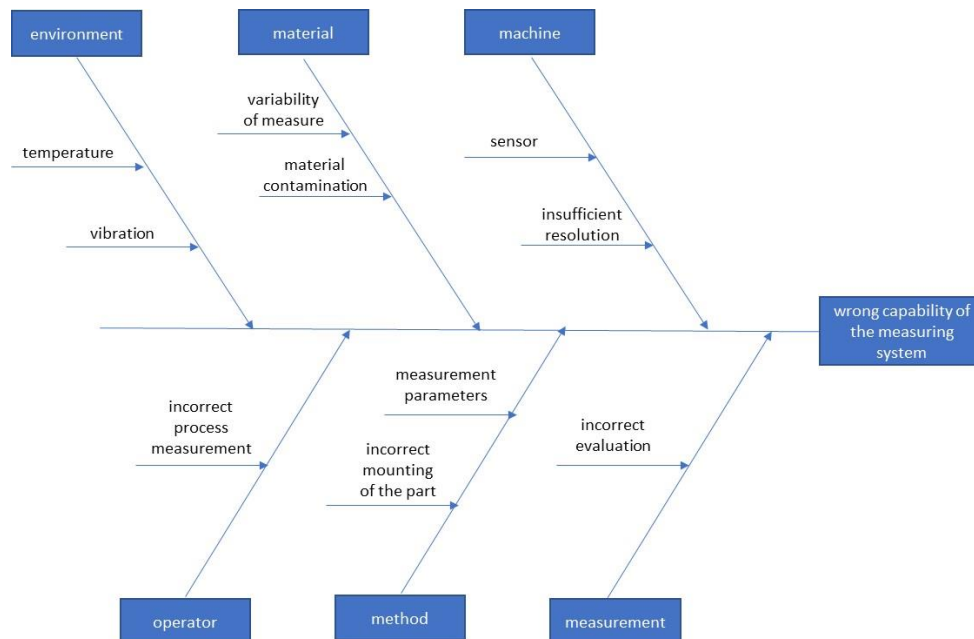


Fig. 3 Cause and effect diagram for insufficient capability of the measuring system

Many times more than one factor can act on a certain problem at the same time and the essence of the problem lies in more than one cause, or in their interaction with each other. Further, that the root cause can sometimes be hidden deeper. In our case, the causes in the example were plotted at most to the second level. However, sometimes it is necessary to go deeper, many times to the fourth-fifth level, in finding the cause. Method 5Why? (5Why?) can serve as a good guide in this case, where the questioner tries to find out the root cause by repeating the question "Why did this happen?" until the true root cause is found.

Asking the question "Why?" five times in a row results in finding the deepest cause of the problem. This is an excellent team-building tool that keeps the focus on solving the problem. The 5Why? can be supported by brainstorming, nominal group, force field analysis, and cause and effect diagram to get to the root cause. (Markulik, Turisova, Nagyova, 2019)

The advantages of Ishikawa's diagram would be its simplicity and spontaneity. For its application, many times a blackboard and a marker, or paper and a pen, are enough. It does not require any special training and the staff involved are able to master it after the first use.

I would point to the disadvantage that, in the wider circle of application, workers sometimes tend to identify irrelevant or unlikely factors as root causes. Further, that the diagram itself, while revealing the interaction of various factors, does not assign any weight to them. Therefore, the likelihood of causes needs to be prioritised in some way.

Histogram

The main area of use of the histogram in the ZF organization appears to be the processing and visualization of measurement results. Mainly analyzing the measured values of dimensions in input, process and output control. The histogram is very often part of process capability reports.

As an example for the use of a histogram, one could analyze data from a 3D measuring machine that recorded the symmetry of a shock mount (Fig. 4) over an extended period of time. Symmetry itself is a geometric tolerance that should generally not take on negative values. However, for the sake of indicating the direction of asymmetry, the sign in front of the data is retained in this case, where a negative number indicates a leftward displacement, a positive one a rightward displacement.

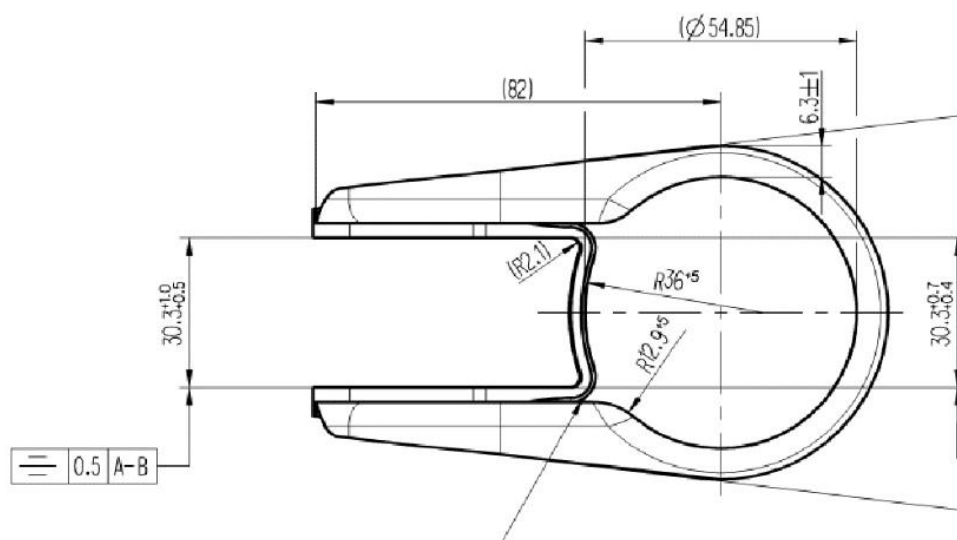


Fig. 4 Symmetry specification according to the drawing documentation

100 measured values were analysed. The measured data were entered in Table 5. A histogram (Fig. 5) was constructed based on this data. Most spreadsheet software is capable of constructing a histogram. For our work we used Minitab software, version 18, which was developed specifically for statistical calculations and finds its application in the field of quality.

Table 1 Measured values

No.	Measurement values									
1-10.	-0,068	-0,131	-0,005	0,018	-0,066	-0,011	0,071	0,278	0,162	0,177
11.-20.	-0,036	-0,057	-0,078	0,114	0,014	0,002	0,165	0,055	0,069	0,019
21.-30.	0	-0,032	0,028	-0,035	-0,001	0,236	0,047	0,016	0,092	0,099
31.-40.	-0,022	-0,018	-0,024	0,036	0,215	0,025	-0,046	0,123	0,078	0,162
41.-50.	-0,064	-0,059	-0,077	0,039	0,186	0,215	0,018	0,093	0,226	0,12
51.-60.	0,064	-0,043	-0,035	0,006	0,005	0,079	0,04	0,156	0,072	0,179
61.-70.	-0,009	-0,037	-0,089	0,072	0,009	0,07	0,197	0,131	0,081	0,013
71.-80.	-0,005	0,007	0,008	0,011	-0,002	0,182	0,128	0,177	0,211	0,068
81.-90.	0,037	0,022	-0,094	0,11	-0,044	0,209	0,118	0,143	0,099	0,138
91.-100.	-0,032	0,024	-0,072	0,078	0,033	0,2	0,142	0,065	0,248	0,253

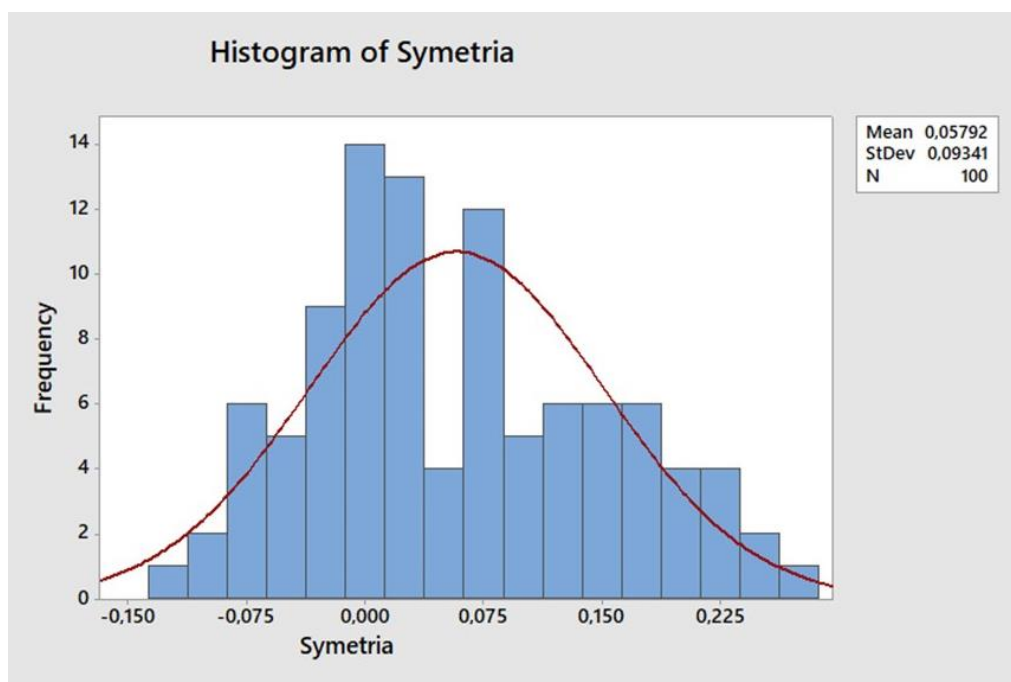


Fig. 4 Histogram

The measured data in the region of 0.05 mm. This may be due to an insufficient number of measured values. It is also clear from the histogram that a few parts had symmetry measured out of tolerance.

We would like to note that even though the measured data has been available for a long time and the 3D measuring machine is set to store the measurement data by default, that particular data has never been displayed as a histogram before. This is a pity, because a clear histogram could help the involved staff to solve possible problems or to analyse definable causes.

CONCLUSION

It should be noted that ZF uses most of the above methods... However, their use is many times "out of habit", without deeper meaning for the staff involved. This is where I see the main focus of improvement opportunities.

A clear list shall be kept of supplier complaints. However, with an up-to-date Pareto analysis, the Supplier Development Department would be able to react promptly to the most

serious problems and focus on the most problematic hotspots in terms of suppliers, materials, geographic regions and other aspects. Based on the 80:20 imbalance principle, maximum results could thus be achieved with minimum effort.

Our suggestion regarding the cause and effect diagram and the flow chart is to familiarise a wider range of staff with these tools. Their simplicity and spontaneity make them applicable to a wide range of problems.

The ZF organisation has appropriate facilities for data collection. Control plans prescribe monitoring of the process at prescribed intervals. Many modern measuring instruments are able to record results over a long period of time and, thanks to suitable interfaces, to process them. The same applies to production machines. The main problem we see is that the data collected is often only available to a small number of workers. For example, if a quality planner needs to prove the delivery capability of a certain purchased component to a customer, he always has to bother the input quality worker with his request. Although sharing such data requires minimal effort thanks to modern information technology. However, it requires a standardised process.

Another option for improvement is real-time online data processing. Most of the company's analyses are done based on customer requests or when a problem occurs. In the case of online processing of results, problems could be avoided because any process anomalies would be able to be captured by histograms and control charts as soon as they occur.

However, as we said at the outset, any quality tool becomes meaningless if it is not properly understood. It is therefore most important to guide staff to understand and use the appropriate tools on a daily basis. Training and seminars are certainly helpful, but it is the day-to-day problems and the example of more experienced colleagues that most influence development.

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Application of Lean Methods in Prototype Production

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Abstract: *The paper focuses on solving the problem of wastage of materials in the assembly workplace in the form of searching, waiting, transporting and other unproductive activities. It offers a review and description of the theoretical knowledge on the current state of the problem addressed in the field of lean manufacturing, which is used in the practical part to solve the problems in the organization. Appropriate solutions to problems in the workplace are introduced. The prerequisite for the introduction of Lean methods is a positive impact on the significant indicators of the organization and on its performance in the long term. As a result of the introduction of Lean, a positive impact on the key indicators of the organisation is achieved.*

Keywords: 7S method, lean manufacturing, assembly,

INTRODUCTION

Organisations are trying to apply or look for ways to put into practice successful elements of lean manufacturing. In any organisation, not just a manufacturing organisation, a large volume of items and documentation will build up over time. The 7S method is the introduction of a clear, clean and safe workplace with the aim of maintaining this state using the standards created.

Directly transferring and copying practices from car companies may not work. On the contrary, transferring principles with an effort to adapt them is the right way to reap the benefits of lean manufacturing. (Kiran, 2019)

Observation of the workplace and communication with staff revealed visible deficiencies.

The results are incorporated and evaluated using lean manufacturing tools and methods. Design of warehouse division due to the need to shorten the material flow, challenging and constant overflow flow in the original warehouse. Efficient tool storage in the form of new toolboxes and a dispensing cabinet to eliminate time loss during working hours. (Burieta, 2013)

Nowadays, wasting time and money causes organizations to lose position and make them unsuccessful in the competition for customers. Customers are placing increasing emphasis on speed, quality, low cost, while emerging methods and technologies are growing in importance. (Košturiak et al., 2006) The aim was to analyse the processes in the assembly workplace and to select the appropriate lean manufacturing methods with a view to eliminating waste. The introduction of lean manufacturing methods is intended to reduce tool searching during work activities and thus avoid unnecessary shifts on the workplace.

MATERIALS AND METHODS

The observational method was used to analyse the workplace with the intention of creating an overview of the current situation and an overview of the problems occurring in the workplace. This was carried out at the assembly and warehouse sites. A simple hierarchical organisational structure is created to record the importance of roles, which operates through top-down communication.

Optimization of the 7S method

The first step was followed by an important optimization of the neglected 5S method, which we extended with two additional steps. After increasing the mentioned two steps which are safety and environment, we further referred the method as 7S. The optimization at the beginning included familiarization with the method and the formation of the work team. Optimizing the method and making it work efficiently in the workplace also consisted of discussing it with individual workers and keeping their mindsets on the correctness of the

steps. In Fig. 1, the sequence of steps for optimizing the 7S method is created using a flow chart.

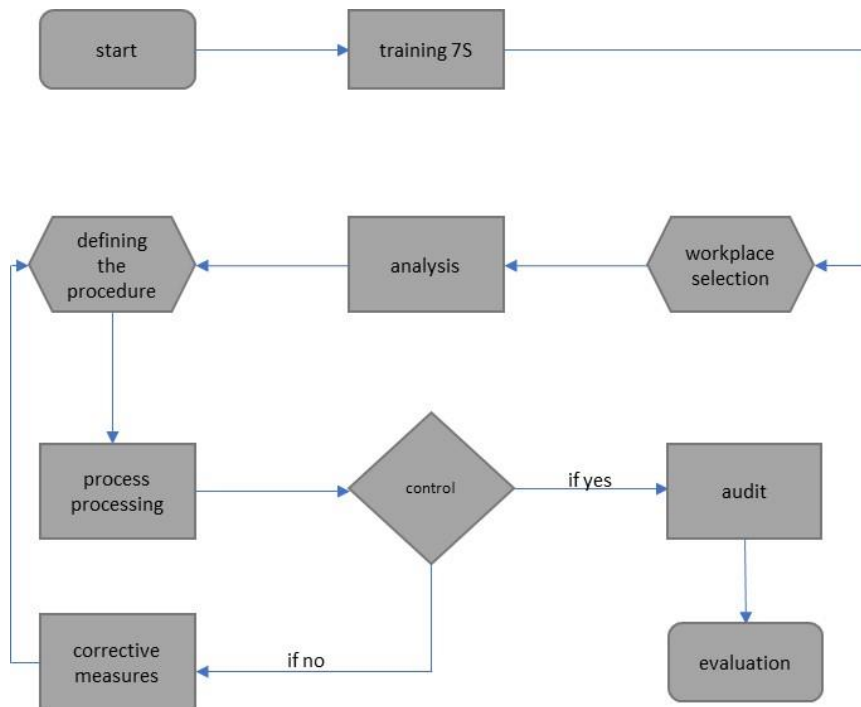


Fig. 1 Procedure for implementing the 7S method

RESULTS

On the assembly floor, he is constantly working on assembling assemblies and sub-assemblies. Subsequently individual assemblies are completed, tested and, if necessary, adjusted according to the customer's needs. Quite a large part of the aforementioned assemblies comes from the parent company based abroad. This workplace also deals with the assembly of complete single purpose machines. Also, individual machine components are tested here and adjusted to the required parameters. Tests are carried out for the safety and correct operation of the machine. Critical points are analysed and solutions are proposed.



Fig. 2 Tools for assembly

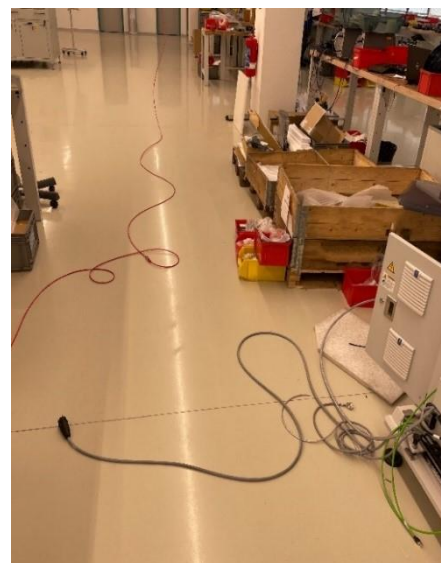


Fig. 3 Space between workbench and machine



Fig. 4 Small material trolleys

The workstation also includes material trays with double-sided design, moving on wheels. Plastic boxes for small material are inserted in the racks, marked with a label for clarity of the stored material. In Fig. 4 we can see what such a trolley can look like with prolonged neglect, and we'll summarise in a few points what in the workplace can cause. This is what a cluttered material trolley can do:

- poor orientation in the workplace,
- increasing unproductive times, wastage in the workplace.

The goal is to achieve an efficient and lean workplace by implementing a 7S system with precise and clearly defined steps that will not arouse worker resistance and will not disrupt the production flow of the organization. Furthermore, it is necessary to acquaint all stakeholders with the basic ideas and guiding principles of the 7S, to present the planned status and, most importantly, to convince the employees of the correctness of the planned actions. It is necessary to make every single employee take the 7S method as a tool to increase performance and reduce the workload. The reason for implementing the method in the assembly workplace was the data showing the least compliant waste factor compared to other workplaces. Based on the organisation's requirement, we decided that the implementation of the method would be carried out at the assembly workplace. (Tóth, 2021)

Sort

Workplace sorting is used to appropriately separate items necessary for the job from unwanted items. First and foremost, we focus on tools, their quantity and condition. Once this data was obtained, the organization and subsequent sorting of unneeded tools and other unwanted items found on the job site began (Fig. 5).



Fig. 5 Example of sorted tools

Next, the team addressed the removal of obstacles placed at locations that workers walk over and have to navigate around. And last but not least is the warehouse where unneeded items are taking up potential storage space. All of the discarded but still usable items have been moved to the old warehouse in the building next door so that they continue to take up space on the site.

Systematize

Systematization of resources and materials follows as the next step after sorting. The goal is to organize and label all equipment and tools so that they are easily visible and we minimize unnecessary staff movement and waste. The workplace will be arranged in accordance with the requirement of the workers working in that workplace (Fig. 6). Only those items that are necessary for the production of the product itself, i.e. add value to the product, will be present on the workstation. For cabinets and objects that contain various tools, jigs, etc., an inventory index will be created, which is actually a list of items in that object. For each item, the number in which it will be located in that location is determined for a better overview.



Fig. 6 Example of marking a small material box

Clean

In the cleaning step we focus on removing dirt such as dust, grime and all other unnecessary items because one of the conditions for efficient work is to have clean surroundings. During the implementation of the method, a large area cleaning was carried out. The cleaning of assembly tables and their surroundings, where the movement and work activities of the workers are most represented, was mainly undertaken. The assembly procedure states that the worker must clean the work area conscientiously before starting work. Also, before the end of the shift, set aside a short time to restore the work area to its original condition by removing clutter. This will be done by a simple documentary guide showing the area as it should look. The organisation has two staff members who look after the cleanliness of the floor and the less frequented areas in the building.

Containers for different types of waste are located at the workplace, they are placed near the workplace with the highest waste production, i.e. assembly. Their removal is taken care of on a daily basis by an authorised employee of the organisation.

Standardize

The constant repetition of the previous steps will ensure order for a time, but standardizing them will ensure their constant adherence and prevent the deterioration of the time-acquired state of the method's implementation (Fig. 7). Standards will be established for all changes relating to the previous steps as well.



Fig. 7 Assembly table standard

Keep

When it comes to maintenance, it will be up to the assembly workers to be disciplined in meeting the established standards for efficient, waste-free operation of the workplace. We know from our own experience that following standardized and specified procedures is sometimes very burdensome for workers, so we propose to introduce incentive rewards for adherence to the written standards. The monitoring and promotion of the established standards would be carried out in the form of departmental meetings, organised by the head of the department, in which the workers themselves could also contribute with their comments and corrections. In this way, an endless cycle of discipline would be created, which would contribute to the positive effect of the growth of the department. A board will be created to be placed in the assembly area of the workstation, which will contain all the norms, procedures and standards for the implementation of the 7S method. It is recommended that periodic audits be conducted to show progress compared to past status. (Tóth, 2021)

Security

The organisation is obliged to continuously address issues regarding safety at work. Safety at work means making the workplace excessively safe. The previous steps of the 7S method also contribute to safety, such as the marking of premises, which helps to prevent accidents caused by moving objects or to reduce the severity of accidents due to the late availability of emergency equipment. The sixth step of the method seeks to achieve zero injuries in the workplace.

In order to achieve good safety results, it is necessary to comply with all the principles of safety at work such as the use of personal protective equipment, proper use of tools and tools without damage. Contribute not only to the visual effect of the workplace, but also in terms of safety. Therefore, a standard of workwear for the assembly worker has been created, prominently displayed on the standards board created.

Environment

The definition of a successful organisation includes environmental performance. Environmental issues are now being decoupled from social aspects and are making themselves known, particularly due to the increasing trend towards environmental protection (Fig. 8). The role of the organisation is to encourage all employees to recycle by informing them and providing them with the necessary equipment to enable them to do so.



Fig. 8 Recycling bins with recycling principles

There will be collection bins at the workplace adjacent to each desk and also shared collection bins. This includes recycling signage, clearly marked bins and communication of recycling policies.

CONCLUSION

Many organizations are striving to implement lean manufacturing principles and develop their own concept of tools, techniques and methods. Some organizations use the same method under a different name, but it is more important to use lean manufacturing tools and methods correctly to eliminate the basic types of waste in the workplace than it is to name them correctly and appropriately.

The analysis of the assembly and warehouse department highlights weaknesses that undermine the proper functioning of the organisation. Several types of waste were found. Pallets of material are often stored in the space between the workbench and the machine with the intention of being used and the space cleared as soon as possible. Realistically, however, the planned application and disposal of the material space drags on for several months. On site, the frequently used small material trolleys, which do not have a docking system and the original labelling of the boxes is confusing, create unproductive times with long searches for material.

When working with established tool trolleys, the arrangement of the tools in the drawers breaks down over time. Such cluttered drawers prolong the work execution time by delays.

According to the established procedure, the 7S method was optimized step by step. In the optimization process, we involved the organization's workers without disrupting the production and assured them of the correctness of the steps of the 7S method. Conditions were created where they themselves could come up with their own ideas on what and where improvements could be made. Corrective action was taken on the problems spotted by the workplace analysis. Standards have been created to ensure that the optimised steps of the 7S method are followed at all times. Such a workplace helps to be competitive in today's battle for customers.

When using one warehouse with several off-site storage facilities, the length of material flow was equal to 163 meters. In practice, in order to shorten the material flow, we were able to reduce the length of the material flow by 35 metres after the introduction of the warehouse partitioning design, which amounts to a reduction of more than 20%. An important factor was the elimination of the warehouse spaces located freely in the workplace and the subsequent creation of a warehouse on the assembly floor.

By investing in more modern equipment, we will keep staff movements to a minimum. There have been noticeable shifts in the efficiency of tool storage using new foam-lined tool trolleys to save time during working hours. On average, the new tool trolleys show an improvement of 7% compared to the original condition.

The work was carried out in a manufacturing organisation environment, so each proposal and its implementation had to be carefully considered and then acted upon. In practice, there may be a number of unexpected factors that have not been taken into account and may interfere with the production process.

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Methods of Processes Management in the Organization

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Abstract: *The basis of any successful organization is to provide an action to achieve pre-determined social and economic goals. The economic goal creates profit and on the basis of profit the assumptions for the continued existence of the organization are created. If the profit is correct and sufficient, then the quality of services and products is also good. These actions are closely linked to customer satisfaction. The higher the level of quality management of the organization is, the higher the customer satisfaction and this supports the fact - lower costs and higher prices. The aim of the paper is to analyze the state of production, improvement and optimization of the production process, process management, process sorting and processes improvement.*

Keywords: *optimization, process, Andon, Lean, preparatory process*

INTRODUCTION

Nowadays, it is very important that in process management, methods are followed to streamline production and the whole process. The process can be characterized as a continuous activity that takes place throughout the organizational structure. Process management itself belongs to the group of management activities, because it constantly pays attention to the methods, systems and procedures that are used throughout the production management and production process. Each organization aims to streamline production with the shortest time, but with the best performance. The better the performance and management of the organization is, the better the final overall result and the satisfied the organization and the customer. (Žitňák et al., 2015)

MATERIALS AND METHODS

Production quality management has the task of making the entire production process do exactly what is expected of it and maybe something more. It is important that the organization's management is constantly innovating and that new technologies and methods are used that facilitate the process itself and thus ensure satisfaction with the end result. (Drucker, 2007)

The main goal was to develop an overview of statistical methods used in quality management.

The production process forms a large part of the entire operation of the organization. It is the sum of interacting and overlapping activities that change from inputs to outputs. It is defined as a recurring event that has its goals, customers, inputs, outputs, indicators, resources, and start and end. It is a collection of activities that follow each other and many take place at the same time.

RESULTS

Within the organization, it is extremely important to know the process management and its quality. It is an activity that transforms an organization from a functional orientation to a process-type organization. To comply with this process, we consider the following areas: teamwork, compression of individual jobs, finding the most suitable place for work and the sequence of work.

Improving the quality of the production process helps organizations to increase customer satisfaction, long-term prosperity and continuous economic benefits. Therefore, it is important that organizations implement statistical methods in their processes.

There are several methods for improving the quality of a production process, its efficiency and the productivity of the organization. In this paper, we describe selected management methods used by organizations in managing production processes - ANDON, 5S, Internal 8D and KAIZEN. (Kassa, 2020)

ANDON – visual management

The purpose of the method is to ensure that the departments respond as quickly as possible and to identify the priorities to be used where the problem is located. Based on the type of signalling, the authorized operator is authorized to suspend the process and the production system automatically sends information to the quality and production department about a possible problem. This method is based on traffic lights and is used precisely because it displays the current state of the production process. With the help of colored lights, trained workers can find out in which mode the whole production process works and when it is necessary to cancel and solve a possible problem. A huge advantage of the method is that it effectively reduces time and works on process control. Identified problems can be solved immediately. If a detected problem is found, information is usually sent about the technical fault, or about missing material or incorrect machine settings. As the method is characterized by the fact that we also call it as a light board, the characteristic colors are: white, orange, green and red. Each color characterizes a different state of the organization.

If necessary, the employee uses a button or touch screen and this information is recorded in the system, which sends the information further by SMS or email to the relevant employees.

Color characteristics:

- White – no production, outage (mostly scheduled),
- Orange – tool change,
- Yellow – production process,
- Red – error, fault.

If a problem is detected, the system displays the device on which the error is located and the estimated repair time is also displayed. This must be addressed immediately and those responsible will shut down the entire production process. As soon as the problem is resolved, the cancel button is pressed and the system no longer shows any fault signaling and the production process continues. The manufacturing process that uses this method can check its current status and ongoing processes. When the production process is completed and the finished product is ready for the customer at the end, the signaling lights up green and the entire production process is over. If the production process has not yet been completed, or if an error or fault occurs, the signal lights up red. Then must come an responsible operator who can manipulate the device and evaluate the immediate situation.

Internal 8D

We characterize the method as an analytical technique that solves an unexpected problem. It does not work as a preventive method, but is only used when a problem has arisen that needs to be solved. This method works as a comprehensive team analysis, which aims to solve, identify and investigate the problem. At the beginning of the method, a simple form consisting of 8 parts must be filled out. The use of the method is enforced if the problem that has arisen is not specifically given, therefore it is unknown to the employees and several employees must be used to solve it. The method was established in the automotive industry in America.

The main role of the method can be characterized as: defining and finding the cause of the problem and its task is to take measures that identify and correct the existing problem and prevent a similar problem or error in the production process in the future. At the end of the use of the method, there is a questionnaire, which has the task of serving as a document of the process.

Phases of 8D method:

1. Opening 8D - through the quality manager, which was caused by a complaint / serious failure
2. 8D processing - this operation is performed by the whole team or the master.

3. 8D Approval - The process is approved by the quality manager.

5S

The basic conditions for the production process of high quality products are characterized and it is characterized by any or minimal waste. The basic feature of the method is also the high efficiency of production processes.

The main goal of the method is to improve the working environment in which employees find themselves and to reduce and eliminate losses and recurring errors. It is used in any type of organization.

The 5S method consists of several pillars:

4. SORT –Sorting. The main role of the pillar is to distinguish the essential things from the insignificant and subsequently to remove from the workplace those that are not necessary.

5. STORE –What belongs in the workplace and in what amount it belongs there.

6. SHINE –The area deals with regular cleaning of the workspace so that the items are accessible to everyone.

7. STANDARDIZE – Standardization.

8. SUSTAIN – The area of preserving its place, that is, that each thing still has its designated place. The area of preserving its place, that is, each thing still has its designated place. (Kassa, 2020)

KAIZEN and its importance in improving processes

This method is used to make ongoing and small changes. Its application is mainly in the production phase and focuses on reducing the costs of the production process. This reduction can be achieved by increasing the efficiency of the process, where partial changes in production processes and design are used. Its philosophy is two words, which are: KAI - improvement and ZEN - continuous improvement.

The method focuses mainly on improving work with materials, improving processes in machines, improving production methods and procedures, increasing quality, reducing time, improving working conditions, eliminating unnecessary work during the production process, creating an optimal working climate, safety at work increases and communication is at a high level and employees are satisfied.

Table 1 Advantages of the KAIZEN method

Organization	Employees	Customer	Supplier
Cost reduction	Remuneration	Improving supply quality	Better planning
Improving quality	Self-education	Clarification of delivery dates	Defining requirements
Increasing productivity	Active motivation	Material minimization	Standardization of customer requirements
Improving cleanliness	Teamwork support	Reducing prices	Improving communication with the customer
Improving communication	Increasing safety at work	A better solution of the problem	Optimal climate

CONCLUSION

Nowadays, every production organization must monitor its production processes. Using statistical methods, organizations can evaluate processes and propose preventive or corrective measures, thereby reducing their costs, increasing product quality and increasing competitiveness.

It is important to monitor the constant stability of the production process and the individual machines that carry out the production process. Statistical methods can determine which machines are unnecessary, which can be replaced by other and new machines. Organizations also use machines that show change in variability and statistical methods can

evaluate possible changes in machines. Statistical methods find out which machines can be reorganized and used for another purpose.

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Determination of Comprehensive Durability Indicators

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Abstract: Establishing comprehensive reliability indicators is an important aspect for improving the overall durability of equipment. Comprehensive indicators consist of the determination of reliability indicators such as Mean Time between Failure (MTBF), Failure rate (λ), Mean Time to Repair (MTTR) and availability index (Kp). The objective of this paper was to determine these indices on a selected equipment. The failure modes occurring for the calendar year 2021 were identified. The causes of the failure modes mechanism were identified and a method of fault elimination was proposed. For each failure mode, the length of downtime and repair time in hours were determined. Based on this data, we quantified each indicator. We found that even with high equipment availability, it is necessary to address the reduction of the failure-free indicators, in particular by adopting the proposed measures and consequently by a good preventive maintenance setup. The monitored indicators are also important from an Industry 4.0 perspective, as they are part of key performance indices (KPIs) and contribute to reliability optimization and risk management.

Keywords: Durability, Reliability, MTBF, MTTR, Failure Rate, Availability

INTRODUCTION

When manufacturing the machine, the necessary quality is ensured both by the quality of the parts, and by the quality of the assembly of the machine and its units, by finishing methods and other process indicators. The modern level of development of science and technology makes it possible to achieve any indicators of machine reliability. The decision on the need to improve the quality of products should be based on an economic analysis. Modern manufacturing industries use a high level of automation with complex machines. The function of automated machines is to achieve higher production rate with better quality (Kolte and Uday A, 2017).

An effective operation of process plant depends on the maintenance practices followed and its operating reliability. In process plants having increasing demand for its product, the effective operation is very important. This must be met by increasing its production. Prior to an increase in production, reliability evaluation and maintenance planning are unavoidable (Kiran et al., 2016).

Creation of new technical systems necessitates the search for solutions aimed at improving their quality, reliability and durability. In this regard, the most important task in their design, manufacture and operation consists perhaps in ensuring the reliability of technical systems. When manufacturing the machine, the necessary quality is ensured both by the quality of the parts, and by the quality of the assembly of the machine and its units, by finishing methods and other process indicators. The modern level of development of science and technology makes it possible to achieve any indicators of machine reliability (Goroshko et al., 2018).

Reliability, availability and maintainability is one of several quality management techniques applied to improving efficiency and productivity on food production lines. It can be applied with other total quality management (TQM) tools, that is, failure mode and effect analysis, Pareto analysis, statistical process control, etc (Defense Science Board, 2007).

Reliability is characteristic of an item, generally designed by R, and expressed by the probability that the item will perform its required function under given conditions for a state time interval. Considered qualitatively, reliability can also be defined as the ability of an item to remain functional (Birolini, 1994).

The term "reliability" is often used as an overarching concept that includes availability and maintainability. Reliability in its purest form is more concerned with the probability of a failure occurring over a specified time interval, whereas availability is a measure of something being in a state (mission capable) ready to be tasked (i.e., available).

Maintainability is the parameter concerned with how the system in use can be restored after a failure, while also considering concepts like preventive maintenance and Built-In-Test (BIT), required maintainer skill level, and support equipment. It is often necessary to decompose these upper level requirements into lower level design-related quantitative requirements such as Mean Time Between Failure/Critical Failure (MTBF or MTBCF) and Mean Time To Repair (MTTR) (Tsarouhas, 2012).

Fulfillment of high demands on the availability and safety of the provided function affects the inherent failure rate itself, as well as the method of operation and maintenance of individual devices (Zajíček, 2015).

Kiran et al. (Kiran et al., 2016), a model for improving plant availability has been proposed. By applying this model, an optimum maintenance schedule for the process plant can be formed. Improvement in availability of plant after employing the optimum schedule was calculated. Results indicate that the methodology is successful in identifying the critical equipment's and improving the availability of the system.

FMEA methods and FTA fault tree analysis can be used to improve reliability (Bujna and Matušíková, 2018; Carlson, 2012; Mandal et al., n.d.; Markulík et al., 2021; Yazdi, n.d.).

MATERIALS AND METHODS

Partial procedure:

- Select a subject to track.

The machine is designed for the assembly of ball joints, it is divided into individual step assembly stations. It is divided into 10 stations in which individual steps and assembly checks are carried out.

Table 1 *Parameters of the machine*

Type: 98300
Power 11 kW
Dimensions: length 6.600mm; width; 5.900 mm; height 2.700 mm
Weight: 5200 kg
Tyre pressure: 5.5 - 6.5 bar
Tyre working force: max. 420 N
Working speed of pneumatic piston: max. 1.5 m.s ⁻¹
Total air consumption: 150m ³ /h
Tank capacity: 60 l
Hydraulic pressure: 125 bar
Hydraulic working force: max. 2.2 kN
Total machine power: 11 kW
Machine noise: 74 dB

- Select the monitoring period for individual machines - for the calendar year 2021.
- Monitor the occurrence of faults and their causes.
- Process the information on the cause of the individual faults and break them down into their individual subsystems.
- Quantify and evaluate the faultiest parts of each subsystem of each machine.
- Quantify complex reliability indicators of the whole system.

Indicators monitored:

Mean time between failures

$$MTBF = \frac{t_p}{n} = \frac{\sum_{i=1}^n t_{pi}}{n} \quad (1)$$

where: t_p - cumulative running time, which means the sum of all running times for thunder consideration,

n - number of outages caused by faults.

Fault intensity λ - is the inverse of the mean time between faults. It can also be thought of as the mean frequency of system failures, see relation:

$$\lambda = \frac{1}{MTBF} \quad (2)$$

Mean Time to Repair MTTR- indicates the average value of the repair time.

$$MTTR = \frac{t_{op}}{n} \quad (3)$$

Where:

t_{op} - cumulative repair,

n - number of failures.

Immediate availability factor K_p - expresses the immediate or long-term usability of the object to be repaired. It indicates the probability that at time t the system will be in working order.

$$K_p = \frac{MTBF}{MTBF + MTTR} \quad (5)$$

Using the previous formulas, the following can be determined:

$$K_p = \frac{t_p}{t_p + t_{op}} = \frac{MTBF \cdot n}{MTBF \cdot n + MTTR \cdot n} = \frac{MTBF}{MTBF + MTTR} \quad (6)$$

where: t_p – cumulative operating,

t_o – cumulative repair time.

RESULTS AND DISCUSSION

The individual failures are divided into three basic categories (electrical, mechanical and pneumatic. In the article itself, we have focused on the electrical ones listed in Table 2.

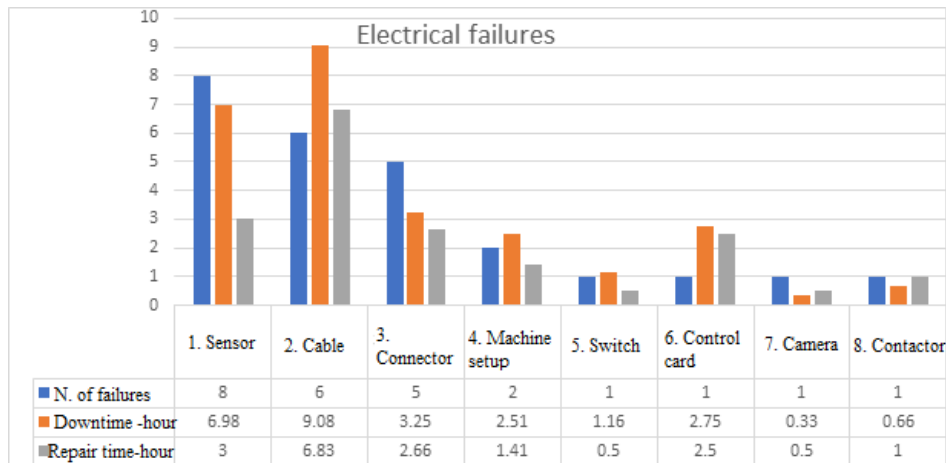


Fig. 1 The most faulty electrical parts on the machine

Fig. 1 shows that the most faulty part of the electrical system on the machine is the encoder. It accounts for up to 32% of the total cause of electrical component failures with the longest downtime caused by wiring faults. There can be several reasons for sensor failures:

- System congestion at some parts or stations.
- Sensor lifetime.
- To the mechanically impaired.

Table 2 *Description of electrical failures on the machine*

Electrical faults on the machine			
Length of downtime [h]	Description of the fault	Description of the fault rectification	Repair duration [h]
1:10:49	Non-functional auto button	Switch/terminator - setting	0:30:00
0:43:22	Unable to start the machine, broken circuit breaker	Connector - replacement	0:40:00
0:33:59	Non-functioning cup check	Sensor - replacement	0:30:00
0:17:27	does not feed the delineation ring, flashed the sensor on the jaw	Sensor - replacement	0:15:00
0:39:21	Station error 3	Sensor - adjustment/cleaning	0:20:00
1:28:41	Station - damaged sensor thread	Sensor - replacement	0:30:00
0:33:11	Station 1-camera	Camera - create/change product	0:30:00
1:00:00	Station 4-rotating arm for cup	Connector - repair/cleaning	1:00:00
0:34:49	Station 6 can't set the sensors to rings	Sensor - adjustment/cleaning	0:35:00
4:40:43	Station 8 - taxi error	Cable - repair	2:30:00
0:49:02	jaws for segment control do not stay in the basic position	Cable - replacement	0:50:00
0:27:03	Station 5 lifting unit does not extend pin to measure	Connector - repair/cleaning	0:25:00
1:03:31	lack of cups in the drum, hopper does not push the cups into the drum	Cable - replacement	1:00:00
1:15:50	not enough cups in the drum, the hopper does not push the cups into the drum	Cable - replacement	1:00:00
0:30:05	Station 5 broken sensor	Sensor - replacement	0:30:00
1:50:39	Station 3-micrometer programming	OP panel - machine settings	1:20:00
2:13:16	Station 2 damaged pin presence sensor	Sensor replacement	0:15:00
0:35:00	does not take over the cup from the lubricating mandrel	Connector - repair/cleaning	0:05:00
0:30:00	Broken connector 4.13	Connector - replacement	0:30:00
0:41:30	Station 7-sequencing separator	Sensor - adjustment/cleaning	0:05:00
0:28:21	The vibrating bar on the cups does not turn on	Cable - repair	0:30:00
0:40:00	the infeed conveyor is inoperative	Contactor - replacement	1:00:00
2:45:54	st.4-functional vibrating leaves	Control card - replacement	2:30:00
1:00:06	non-functional regulation of vibration blades	Cable - repair	1:00:00
0:40:26	measurement throws out a lot of OK parts	Machine setup	0:05:00

Table 3 *Calculations of reliability indicators of electrical components of the machine*

Elements of the system	MTBF	λ	MTTR	K_p
Sensor	325	0,003	0,375	0,999
Cable	433,3	0,0023	1,138	0,997
Connector	520	0,0019	0,532	0,999
Machine setup	1300	0,00076	0,705	0,999
Switch	2600	0,00038	0,5	1
Control card	2600	0,00038	2.5	0,999
Camera	2600	0,00038	0,5	1
Contactor	2600	0,00038	1	1

Table 3 shows that all facilities have a high availability factor. Despite the high availability, it is necessary to address the reduction of the availability indicators

On the machine, we propose, due to the observation of faults in the electrical part, to develop statistics on the lifetime of individual types of sensors used on the assembly machine due to the deteriorating quality of individual sensors and to create a market survey for possible cooperation with another supplier of individual sensors. Furthermore, I propose to develop a workshop to optimise the maintenance tasks and to review the individual steps with operators, maintainers and technicians. To increase sensor fouling that causes unnecessary downtime, I propose to optimize the cleaning steps in the TPM document that will focus on cleaning and maintenance of the sensors. The proposed steps may result in an increase in the cost of procuring a new vendor for electronic sensors or purchasing new cleaning products for operators but there should be a noticeable increase in uptime issues and a reduction in overall downtime.

CONCLUSION

Mean time between failure (MTBF), mean time to failure (MTTF) and mean time to repair (MTTR) are the three commonly used key maintenance performance indicators (KPIs). Indicators act as a delay indicator that provides an overview of past events. In this way, they enable proactive measures and help predict future events. The setting of key maintenance performance indicators (KPIs) and key risk indicators (KRIs) is important in terms of a proactive approach to management not only in reliability but also in risk management. This is also an important feature of Industry 4.0.

The MTBF needs to be kept as high as possible to make the system more reliable. This can be achieved by optimizing preventive maintenance.

MTTR needs to be kept as short as possible to reduce equipment downtime. This can be achieved by optimising preventive maintenance. The key is to identify all failure modes. The failure rate λ is the number of failures in a component or piece of equipment over a specified period. It is important to note that the measurement excludes maintenance-related outages. In industrial applications, the failure rate represents past performance based on historical data. But in engineering design, it is also important to predict failure rates.

The availability coefficient is an operating parameter. We found the device to be available at a very high level (almost 100%).

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